



# *Scheduling Activities for the Patrol Boat Force*

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# *Overview*

- Introduction
- The scheduling tasks
- Problem-solving scheme
- Cost formulations
- The software
- Possible further development

# *Introduction*

- CBM: scheduling **crews**, **boats**, **missions**... also maintenances and ports.
- Carried out by CSIRO with DSTO, for the Replacement Patrol Boats project.

# *Scheduling tasks – summary*

- Main tasks:
  - ❖ Set timings for missions and maintenances
  - ❖ Determine assignments of crews to boats
  - ❖ Construct week-by-week schedule of activities for each boat and each crew.
- We assume a 12-month planning period, with one-week granularity of time.
- Multi-crewing makes for complexity and is a primary driver of the project.

# *Scheduling tasks - objectives*

- 1 Spread timings evenly in each mission-group
- 2 Regular operational cycles for crews
- 3a Leave during school holidays
- 3b At least one leave during school holidays
- 3c Spread leave evenly in year
- 3d Desired leave block sizes
- 5 Minimise hand-overs
- 6 Minimise remote hand-overs

# *Scheduling tasks – constraints<sub>1</sub>*

- 1 Include UUC
- 2 Include all planned missions
- 3 Limited boats
- 4 Limited mission-time
- 5 Boats available for surge
- 6 Restricted maintenance facilities in ports
- 7 All missions assigned to crews
- 8 One activity at a time per crew
- 9 Operational workload limit
- 10a Leave quota per crew
- 10b Minimum leave block size

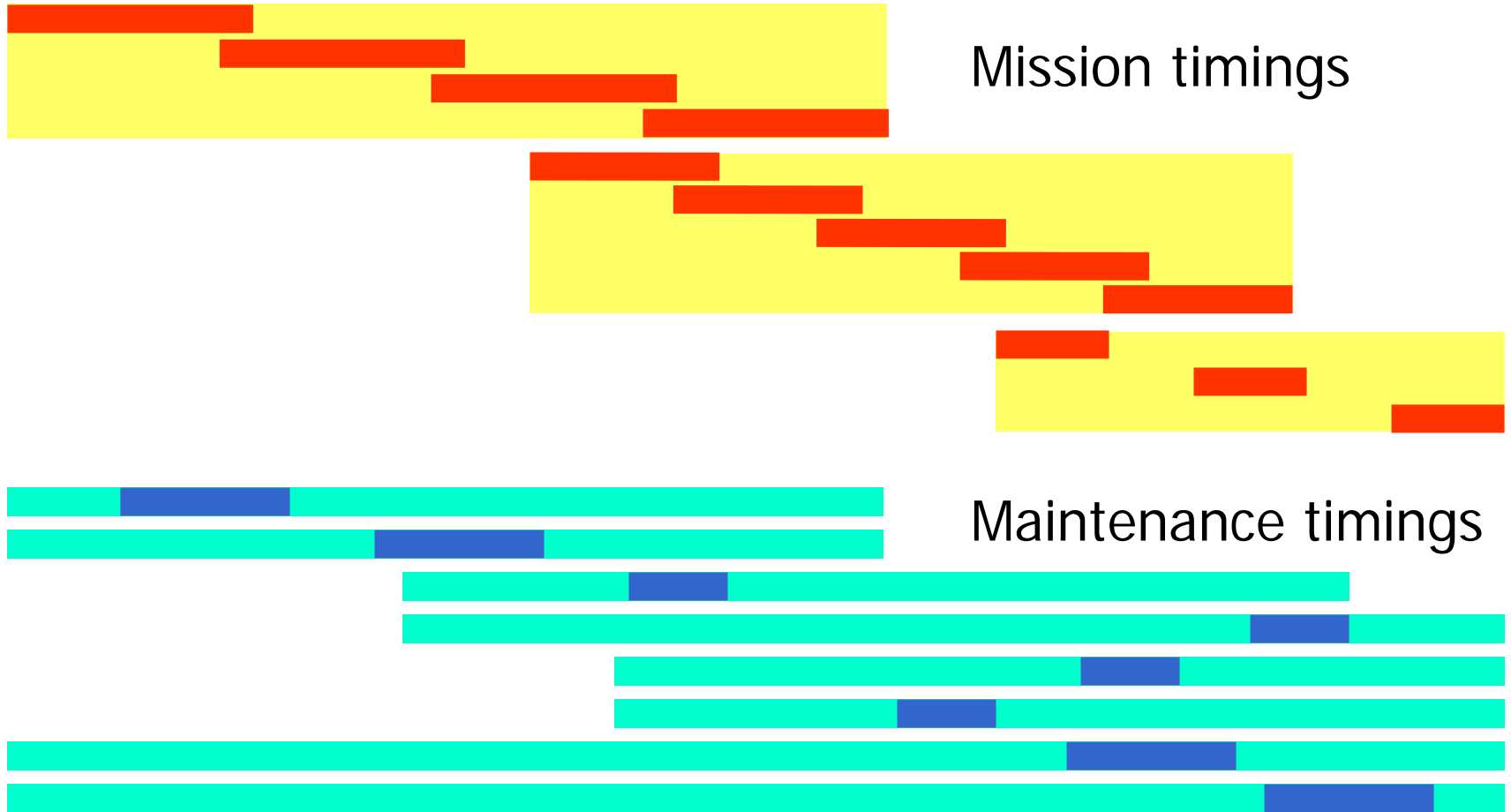
# *Scheduling tasks – constraints<sub>2</sub>*

- 12 At most one workup mission per crew
- 13 Training every operational cycle
- 15 All boat activities assigned to boats
- 16 One activity at a time per boat
- 17 Boat must have crew assigned
- 18 Limit no. of crews assigned to a boat
- 19 Limit no. of boats a crew is assigned to
- 20 Maintenance at crew's home port
- 21 Workup follow-up

# *Problem-solving scheme*

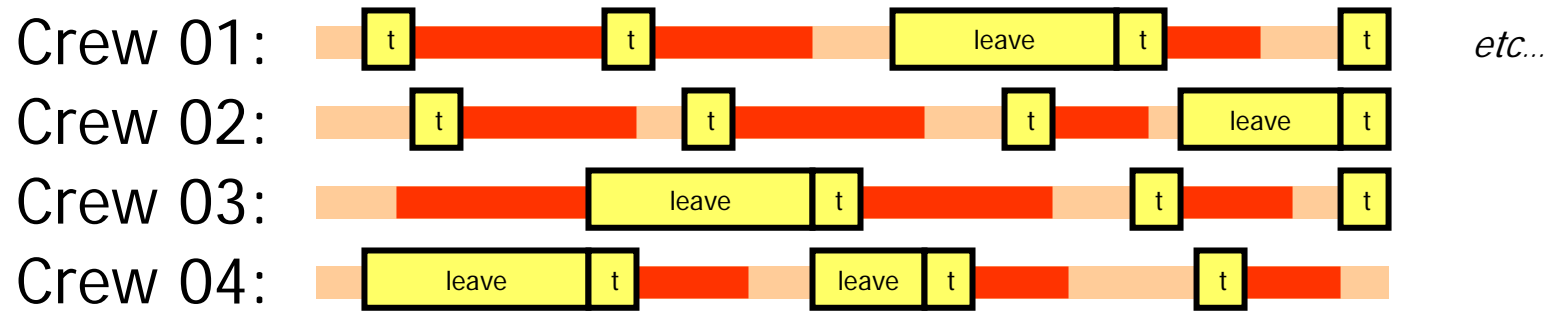
1. Generate a Fleet Activity Schedule (FAS), with timings for all maintenances and missions.
2. Generate a Combined Operations Plan (COP), with maintenances and missions assigned to crews, boats and ports.
3. Define details of leave and training for each crew in the COP.

# *Problem-solving scheme: FAS*



# *Problem-solving scheme: COP*

Crews: week-by-week deployments, leave, training



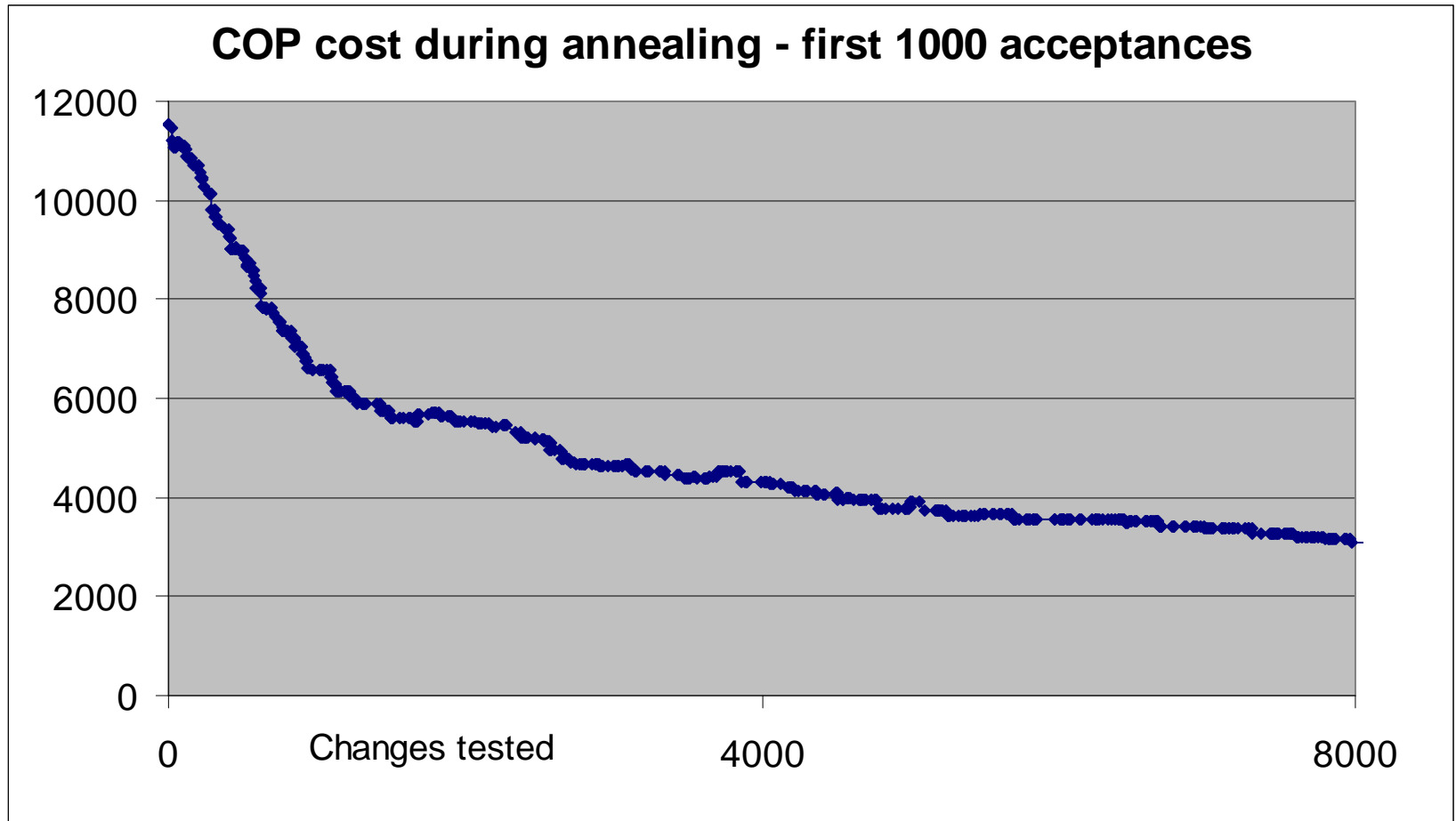
Boats: week-by-week deployments and maintenance



# *Local search techniques*

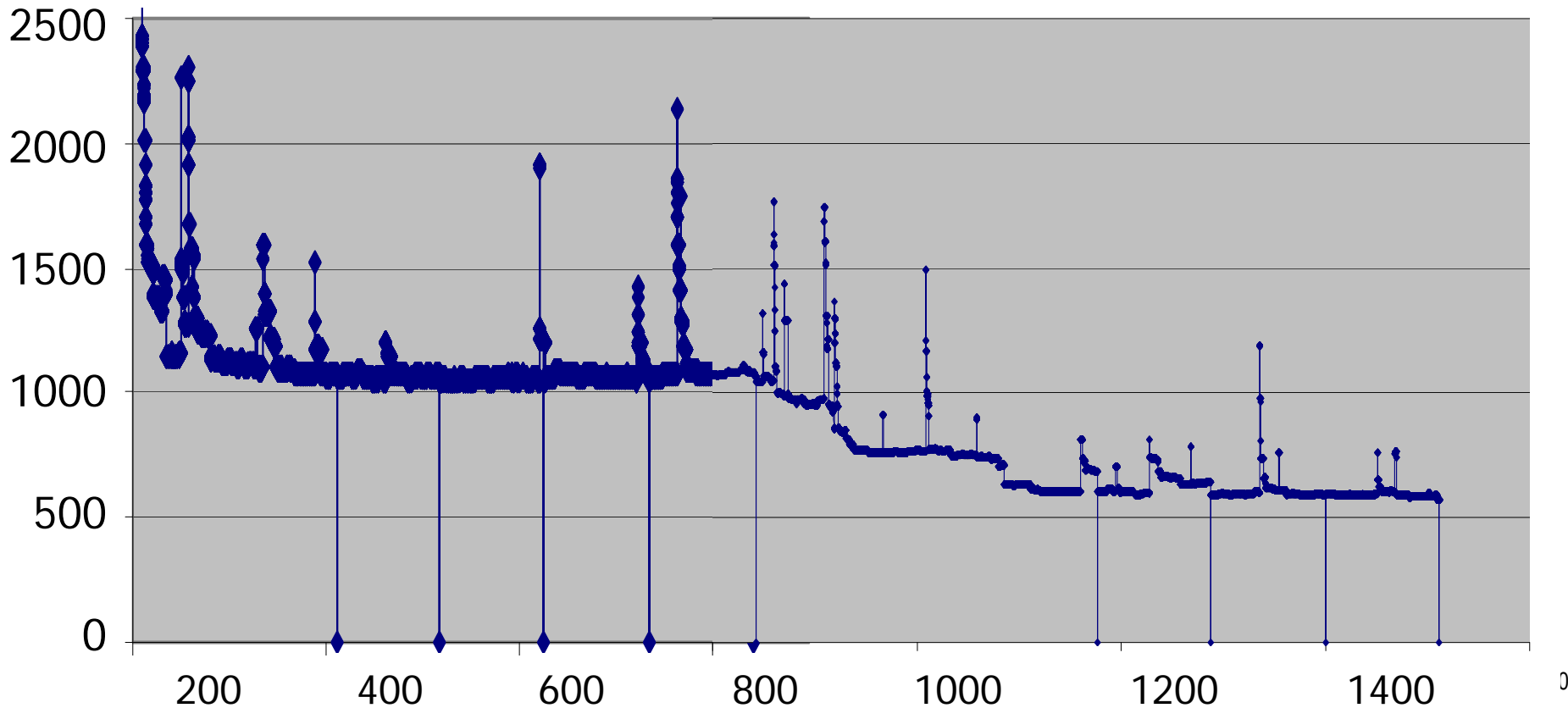
- **Steepest-descent improvement**: take an arbitrary starting plan and make the most-improving small change. Repeat until no further change is possible.
- **Simulated annealing**: like improvement, with temporary reductions in quality. We start “hot” (allowing random changes) and proceed slowly to a “cooled” state, aiming for an “well-ordered” outcome.

# *COP annealing* (11B18CSA01-CopSA-2)



# *COP annealing* (11B18CSA01-CopSA-2)

Cost over 1433718 tries, 65536 acceptances



# *Cost formulation*

- A scheduling plan comprises a FAS and a COP based on the FAS timings.
- For both FAS and COP, overall solution quality is measured as total cost:
  - ❖ Costs due to objectives, e.g. deviations from equal-spaced timings for missions.
  - ❖ Costs due to violations of constraints, e.g. boat-weeks in violation of the surge condition. Some constraints are *hard*, some *soft*.

# *Cost formulation – FAS*

**FAS-01: cost 309.86 (O: 289.86, S: 20.00, H: 0.00)...**

[O1]	Mission-group devs:	169.86	x	1.00	x	1	=	169.86	
[O3a]	Avoid school hols:	120	x	1.00	x	1	=	120.00	
[C3]	Total boats used:	0	x	20.00	x	1	=	0.00	[0 weeks]
[C4]	Monthly miss-times:	0.00	x	10.00	x	1	=	0.00	[0 mths..]
[C5]	Surge available:	2	x	10.00	x	1	=	20.00	[2 weeks]
[C6a]	Maintenance cap:	0	x	20.00	x	1	=	0.00	[0 weeks]

# *Cost formulation – COP*

COP-01: cost 524.0 (O: 384.0, S: 140.0, H: 0.0)...

[O2] Regular op cycles:  $105 \times 1.0 \times 1 = 105.0$

[O3b] School holidays:  $0 \times 1.0 \times 9.0 = 0.0$

[O5] Total handovers:  $21 \times 1.0 \times 9.0 = 189.0$

[O6] Remote handovers:  $2 \times 5.0 \times 9.0 = 90.0$

[C6b] Port capacities:  $0 \times 20.0 \times 1 = 0.0$

[C8\*] One act per crew:  $0 \times 150.0 \times 1 = 0.0$

[C9] Total opnal weeks:  $0 \times 10.0 \times 1 = 0.0$

[C12] Workup/crew  $\leq 1$ :  $0 \times 10.0 \times 1 = 0.0$

[C13] Training/cycle:  $14 \times 10.0 \times 1 = 140.0$

[C16\*] One act per boat:  $0 \times 150.0 \times 1 = 0.0$

[C18] Crews per boat:  $0 \times 10.0 \times 9.0 = 0.0$

[C19] Boats per crew:  $0 \times 10.0 \times 9.0 = 0.0$

[C21] Workup followup:  $0 \times 10.0 \times 9.0 = 0.0$

# *The software*

- CBM runs on a Windows PC, in a command-prompt window.
- I/O is mainly Excel spreadsheets.
- Good solutions for difficult problems can be obtained in 15-60 minutes.
- Technical awareness is required of users.

# *Possible further development – as an operational tool?*

1. Make CBM more user-friendly, with GUI.
2. Allow scheduling over a given calendar period instead of a “standard year”.
3. Accept existing commitments, e.g. at beginning of planning period.
4. Mission prioritization.
5. More fairness for crews
6. Handle new scheduling conditions (squadrons?).